US005159631A

United States Patent [19]

Quan et al.

[11] **Patent Number: 5,159,631**

[45] **Date of Patent: Oct. 27, 1992**

[54] **AUDIO SCRAMBLING SYSTEM USING IN-BAND CARRIER**

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[21] Appl. No.: **514,891**

[22] Filed: **Apr. 26, 1990**

[51] **Int. Cl.**[5] **H04N 7/167**
[52] **U.S. Cl.** **380/19**; 380/38
[58] **Field of Search** 380/19, 31, 32, 38, 380/39, 40, 33, 34

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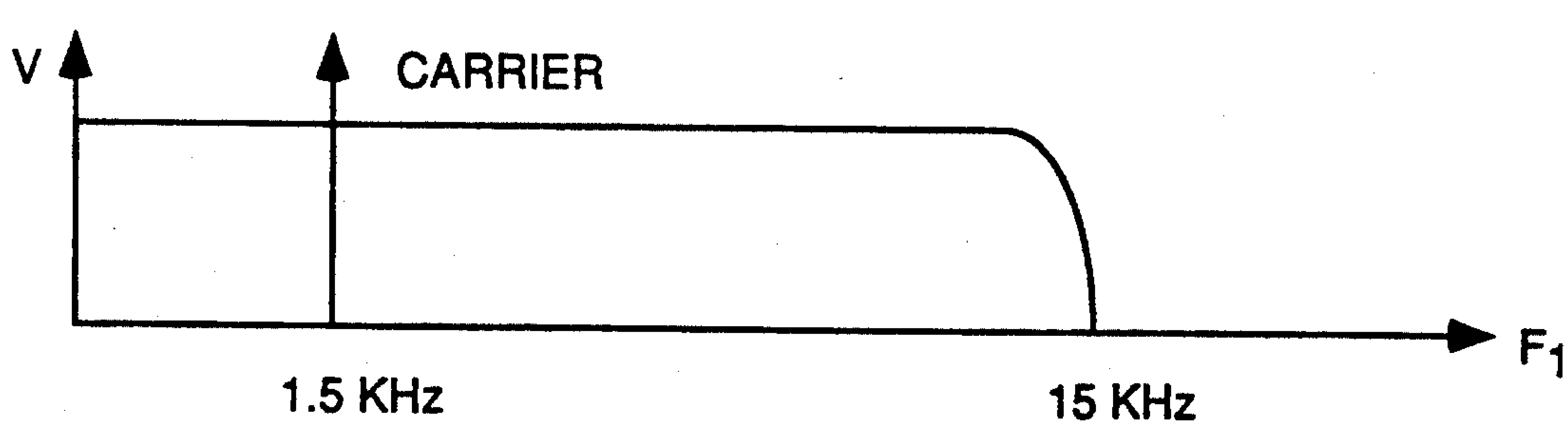
Primary Examiner—Tod R. Swann
Attorney, Agent, or Firm—Skjerven, Morrill, MacPherson, Franklin & Friel

[57] **ABSTRACT**

Audio signals are scrambled by single side band modulating with a modulation signal carrier having a frequency lying within the audio frequency band so that the signals are frequency translated upward. The scrambled audio signals are descrambled after broadcasting or recording/reproducing using a substantially identical modulation carrier signal to restore the original audio signals. Security is enhanced by varying the frequency of the modulation carrier signal in a pseudo random manner in response to start (ACLK) and rate (A0, A1) control signals. The control signals accompany the scrambled audio signals and are used during the descrambling process to aid in the generation of the descrambling carrier modulation signal. The frequency translation technique reduces the adverse effect of wow and flutter frequency fluctuations introduced during recording and reproduction of the audio signals (as compared to systems using frequency spectrum inversion), and also reduces the adverse affect of high frequency headroom crashing experienced in pre-emphasis broadcasting and equalizer recording applications.

32 Claims, 8 Drawing Sheets



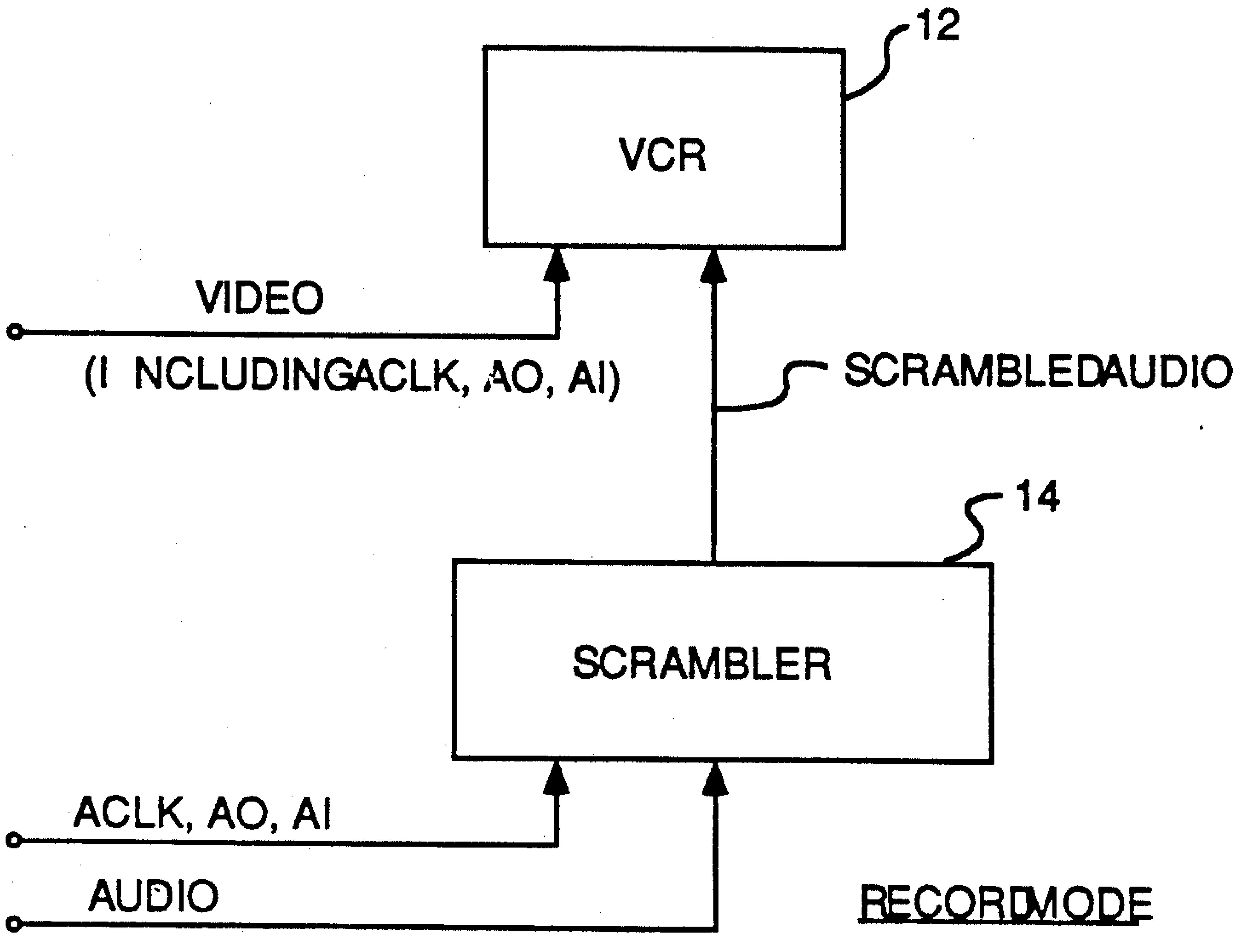
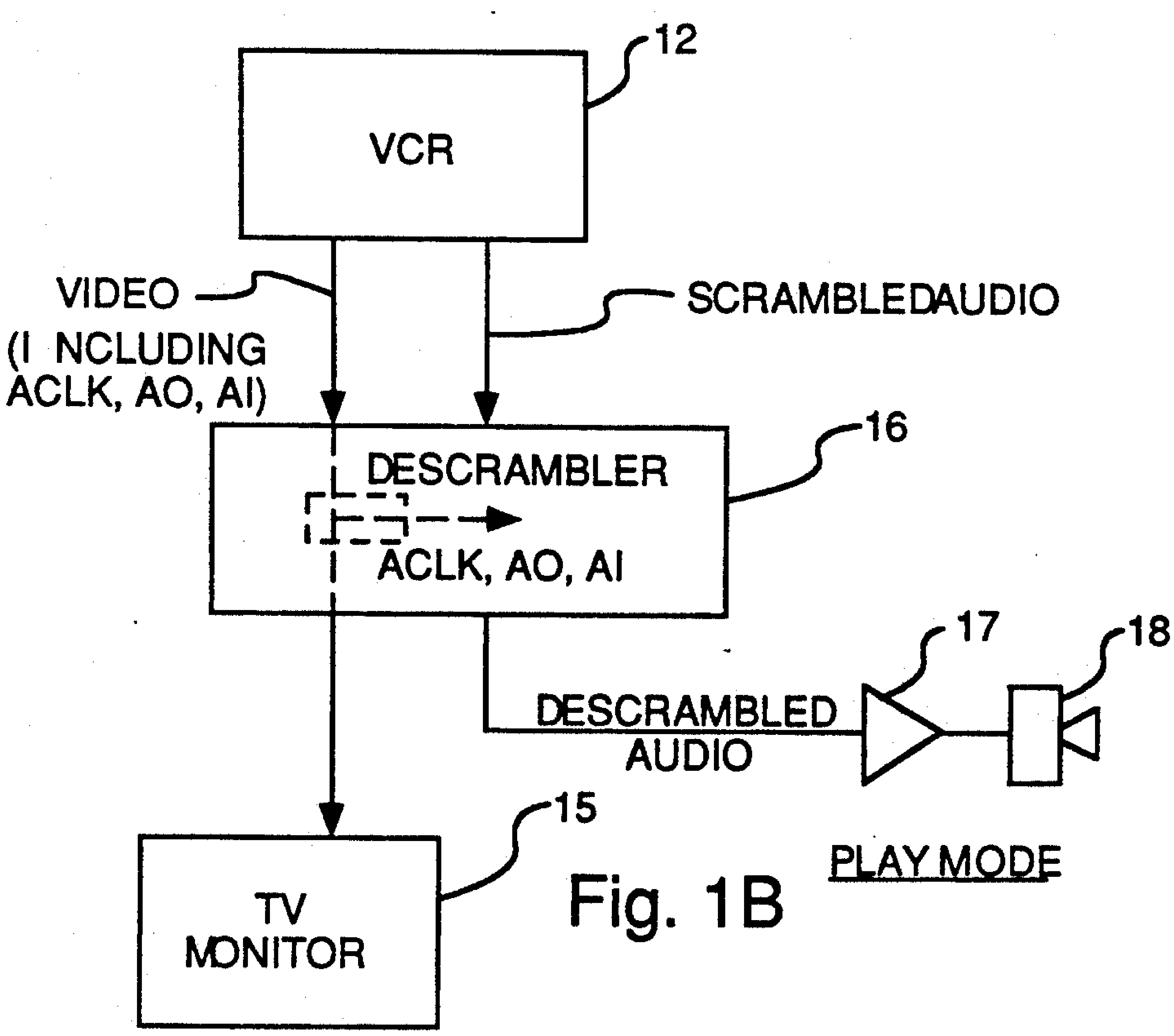

12
VCR
VIDEO
(I NCLUDINGACLK, AO, AI)
SCRAMBLEDAUDIO
14
SCRAMBLER
ACLK, AO, AI
AUDIO
RECORDMODE

Fig. 1A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VCR
VIDEO
(I NCLUDING
ACLK, AO, AI)
SCRAMBLEDAUDIO
16
DESCRAMBLER
ACLK, AO, AI
17
18
DESCRAMBLED
AUDIO
15
TV
MONITOR
PLAY MODE

Fig. 1B

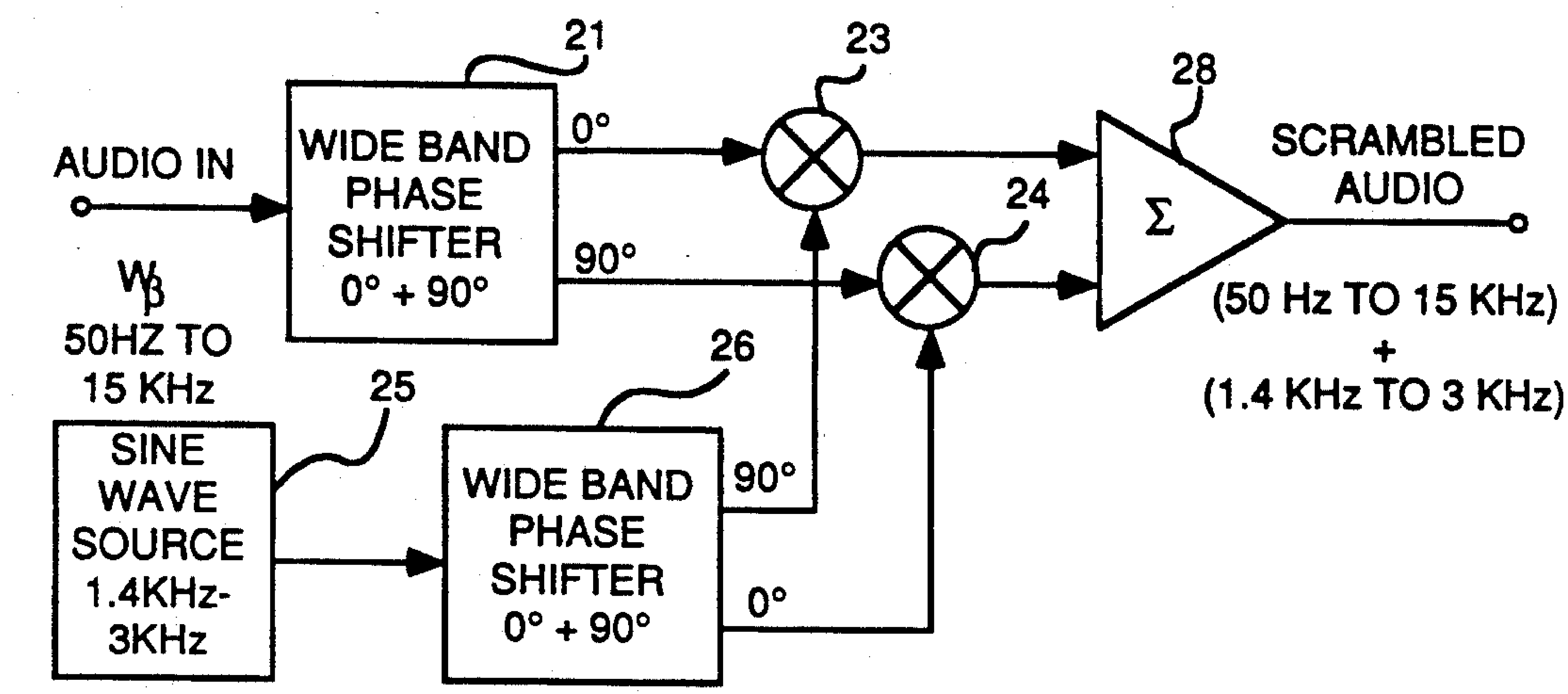


Fig. 2

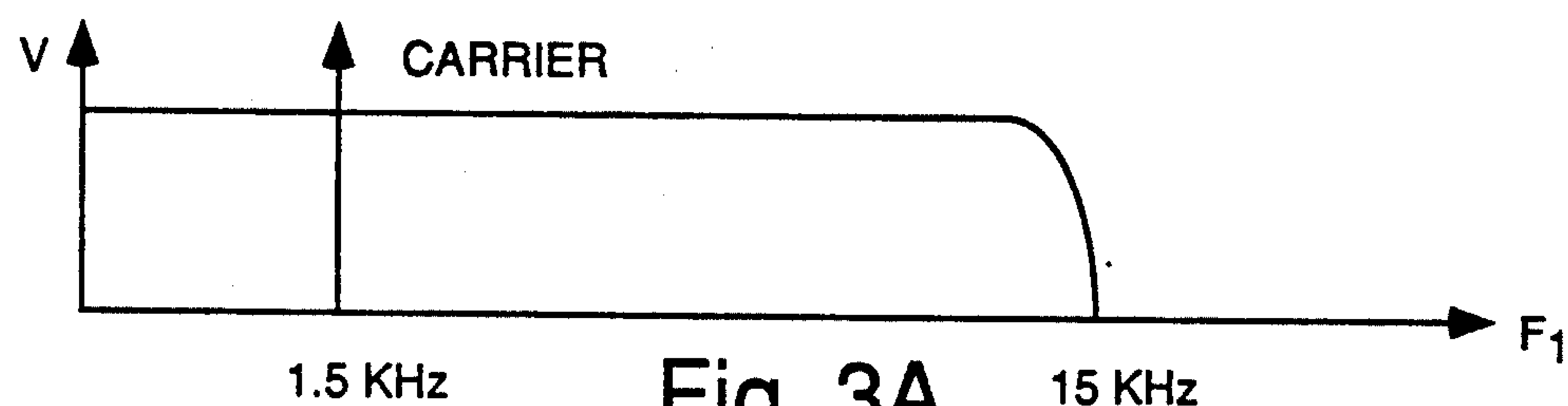


Fig. 3A

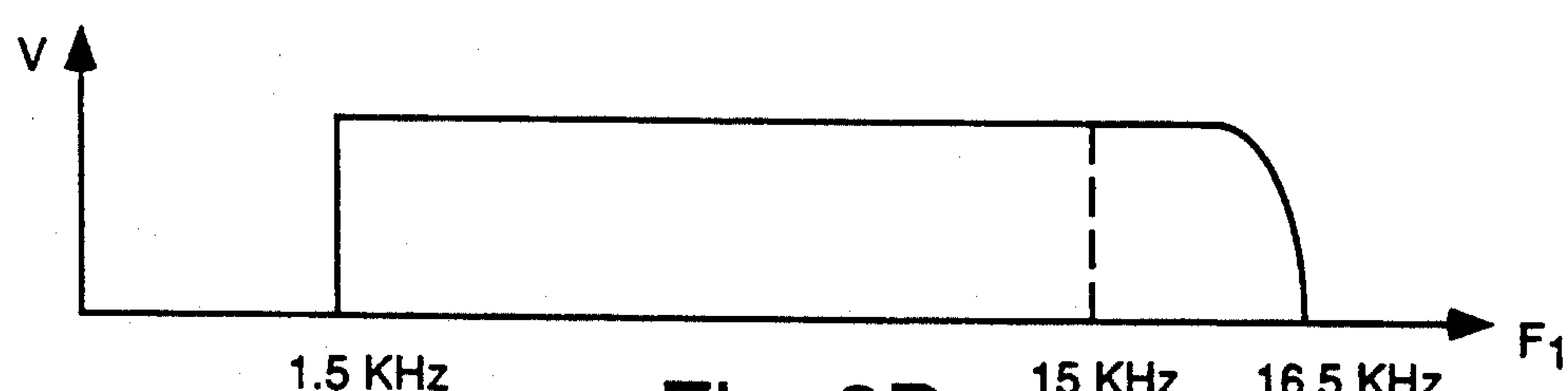


Fig. 3B

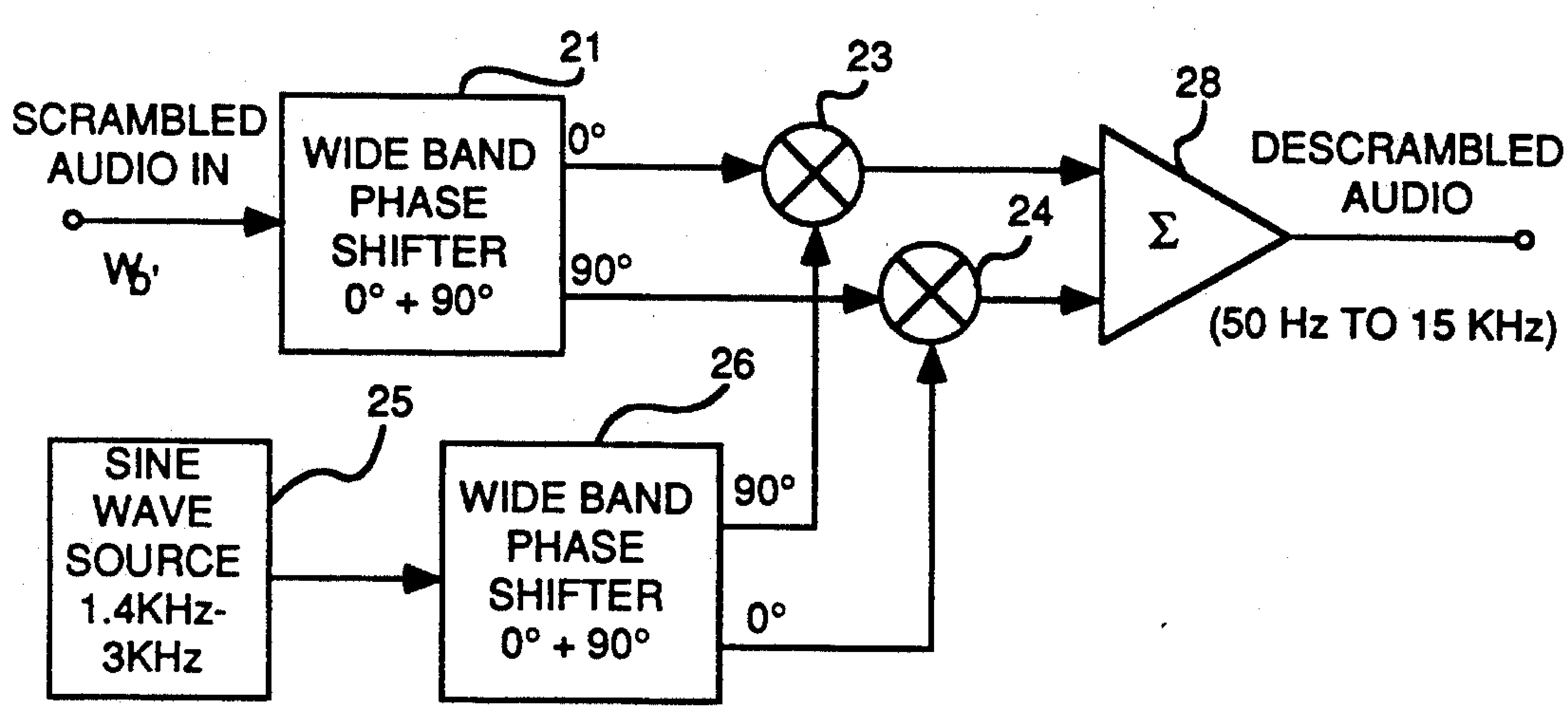


Fig.4

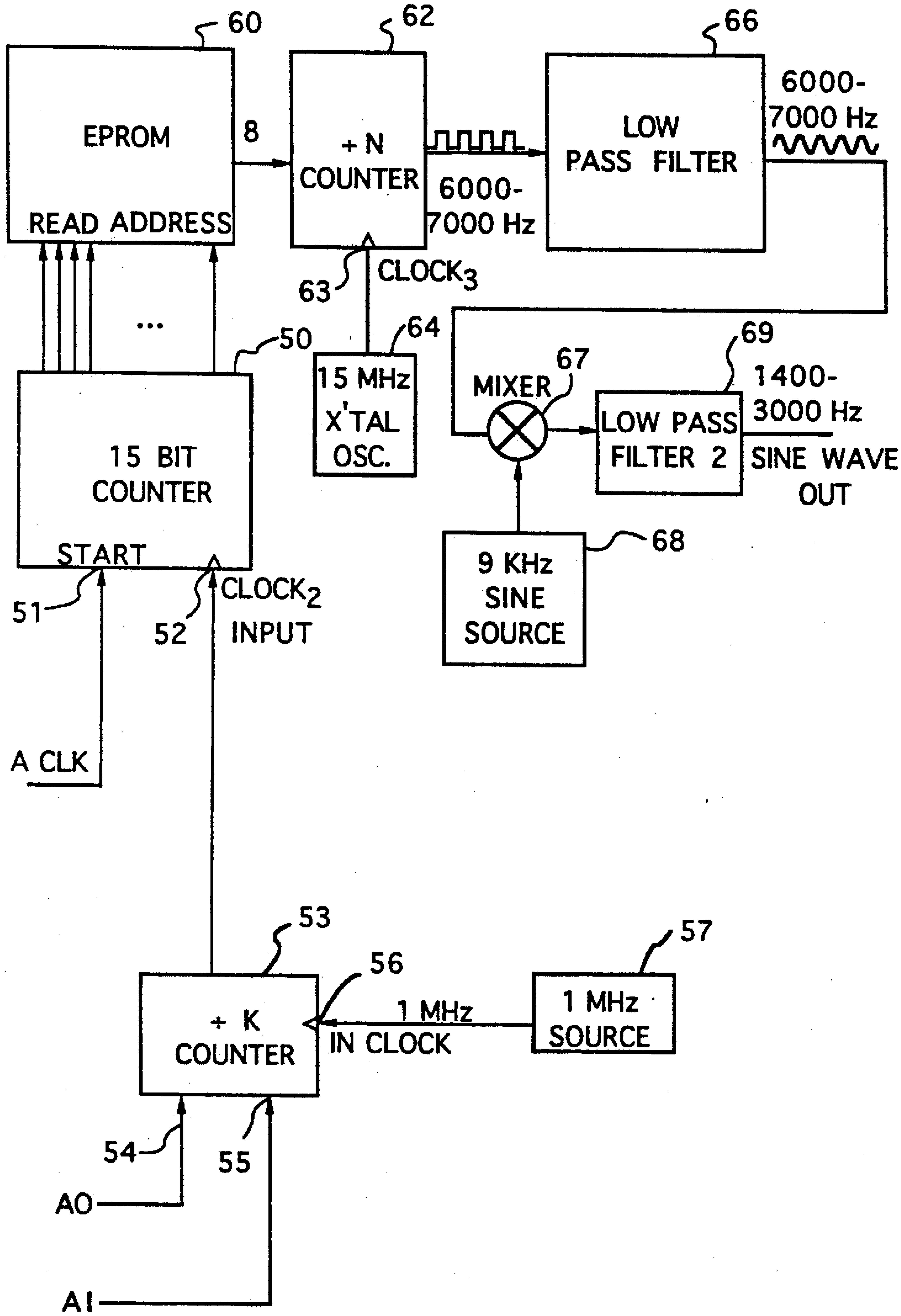

60
EPROM
READ ADDRESS
8
62
÷ N
COUNTER
6000-
7000 Hz
66
LOW
PASS FILTER
6000-
7000 Hz
63
CLOCK3
64
15 MHz
X'TAL
OSC.
50
15 BIT
COUNTER
START
51
52
CLOCK2
INPUT
A CLK
MIXER
67
69
LOW PASS
FILTER 2
1400-
3000 Hz
SINE WAVE
OUT
68
9 KHz
SINE
SOURCE
53
56
÷ K
COUNTER
1 MHz
IN CLOCK
57
1 MHz
SOURCE
54
55
AO
AI

Fig. 5

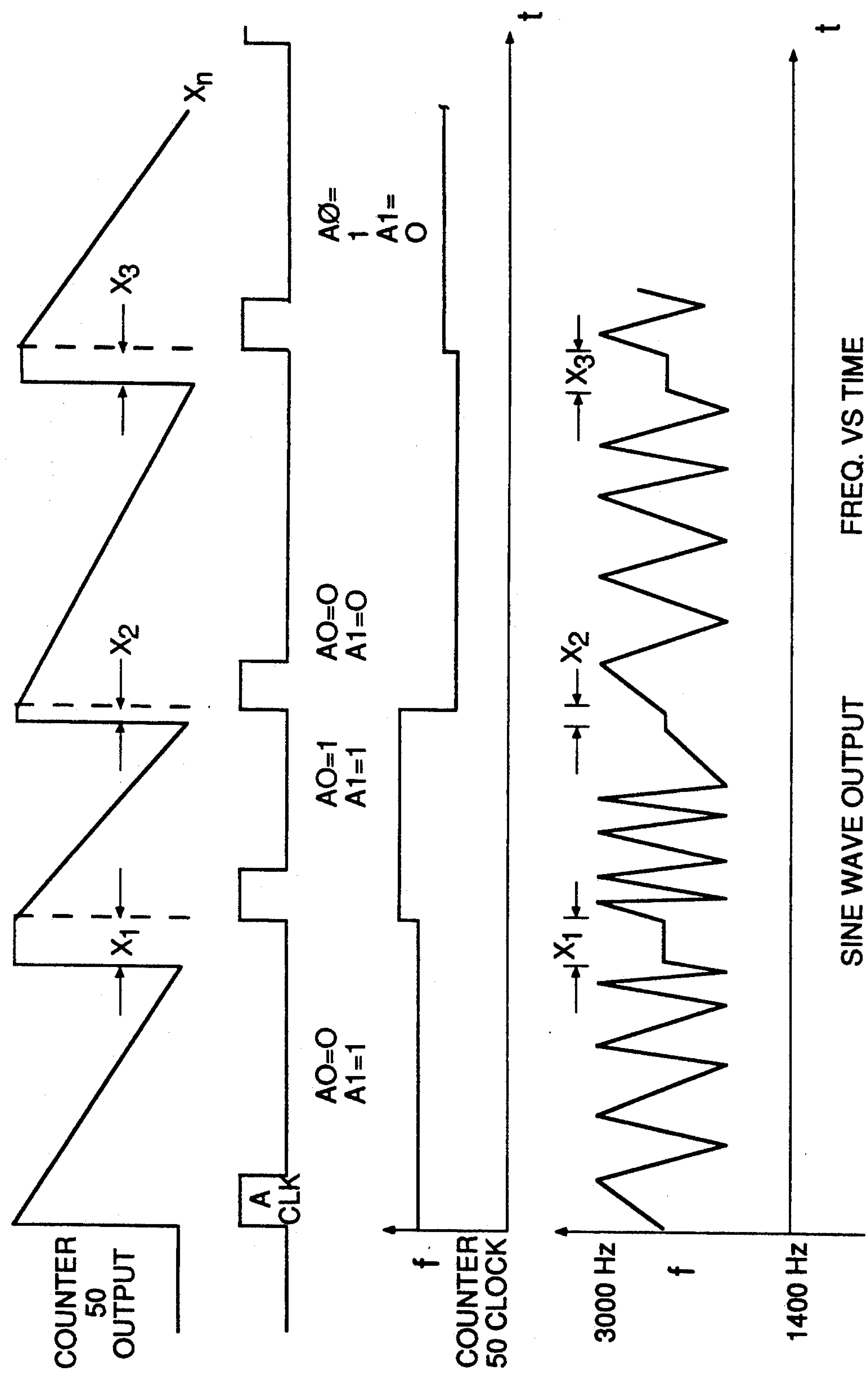


Fig. 6A

Fig. 6B

Fig. 6C

Fig. 6D

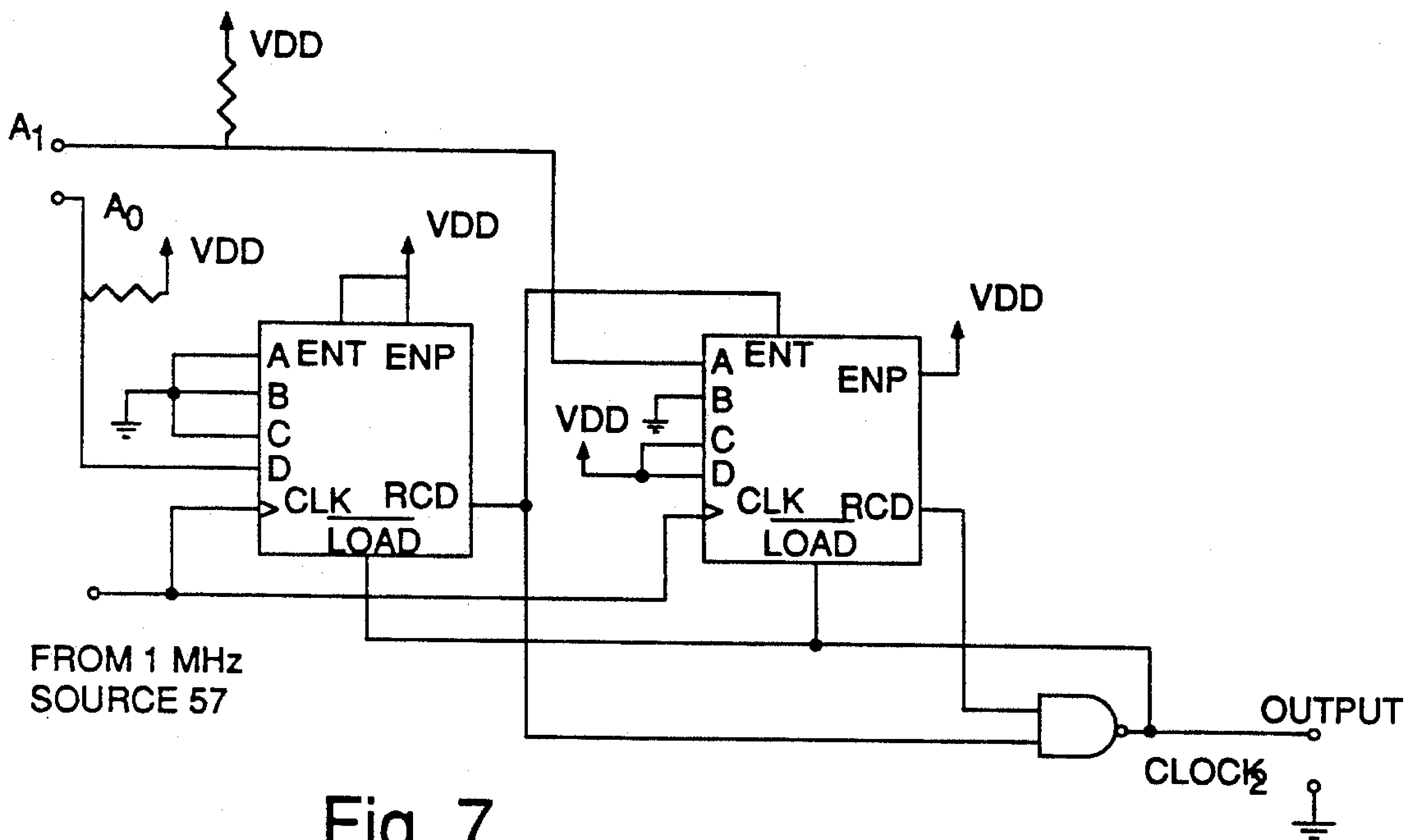

VDD
A1
A0
VDD
VDD
A ENT ENP
B
C
D
CLK RCD
LOAD
VDD
A ENT
ENP
VDD
B
C
D
CLK RCD
LOAD
FROM 1 MHz
SOURCE 57
OUTPUT
CLOCK2

Fig. 7

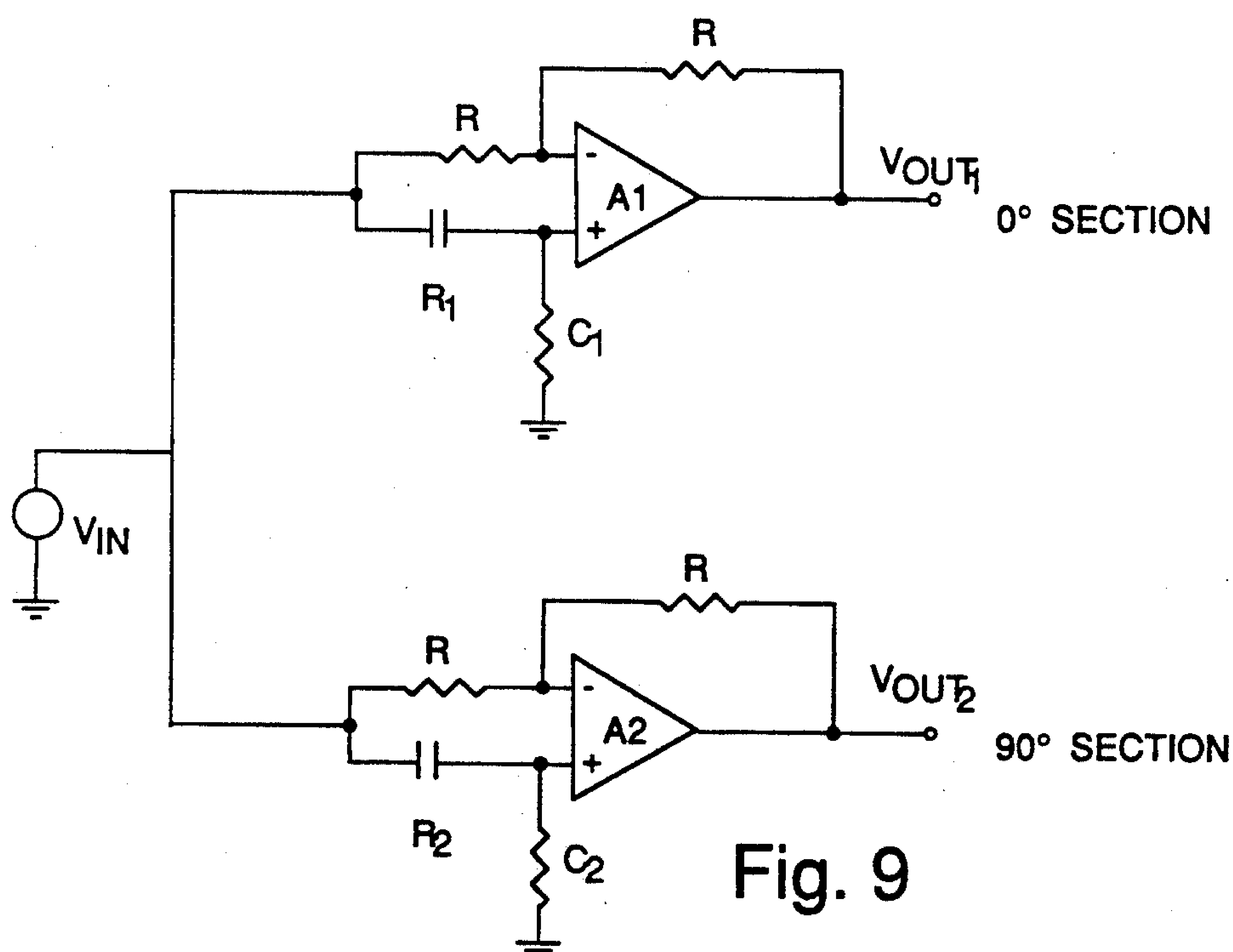
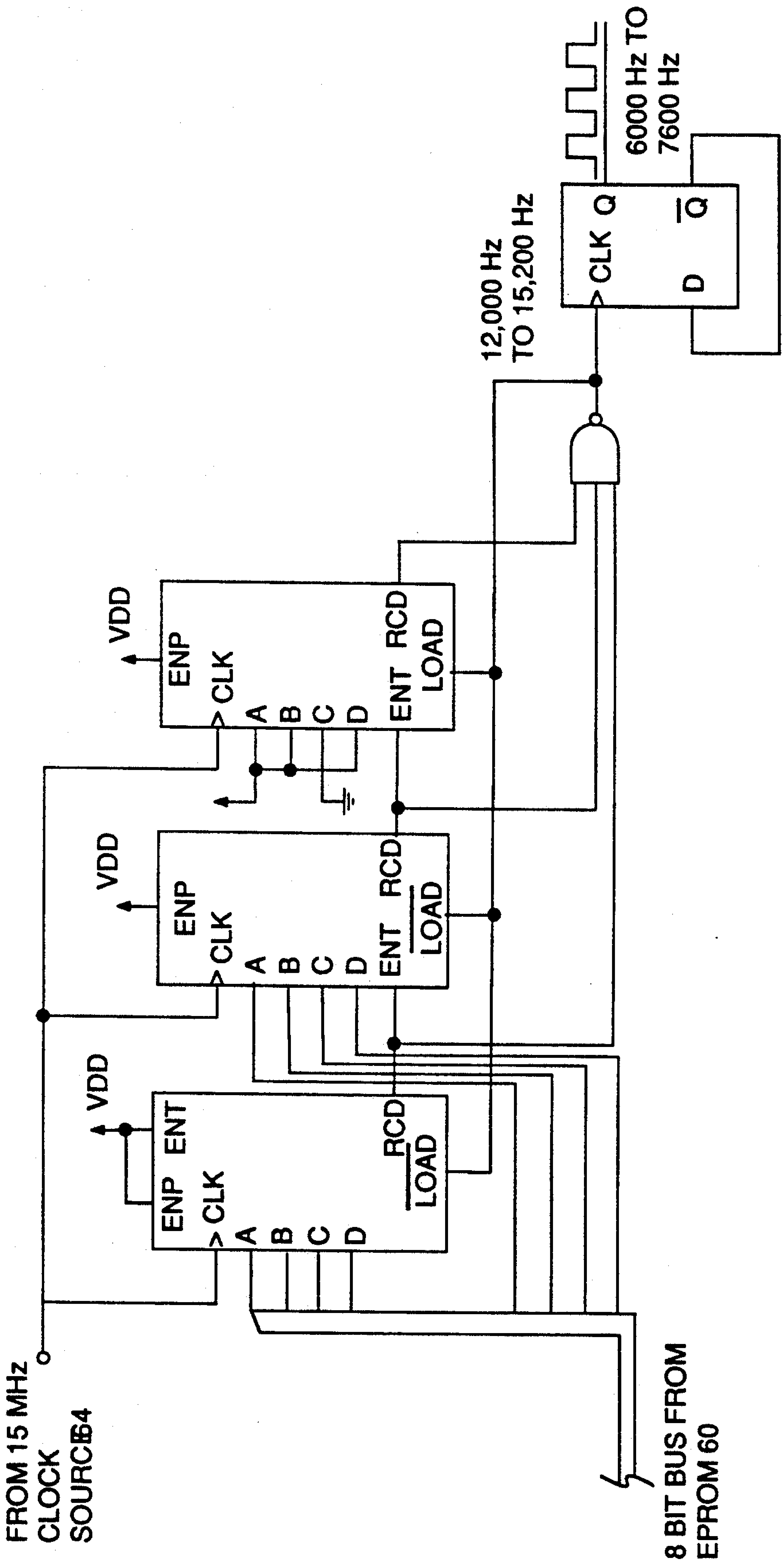

R
R
A1
VOUT1
0° SECTION
R1
C1
VIN
R
R
A2
VOUT2
90° SECTION
R2
C2

Fig. 9



FROM 15 MHz CLOCK SOURCE 64
8 BIT BUS FROM EPROM 60
VDD
ENP
ENT
CLK
A
B
C
D
RCD
LOAD
12,000 Hz TO 15,200 Hz
6000 Hz TO 7600 Hz
Q
D

Fig. 8

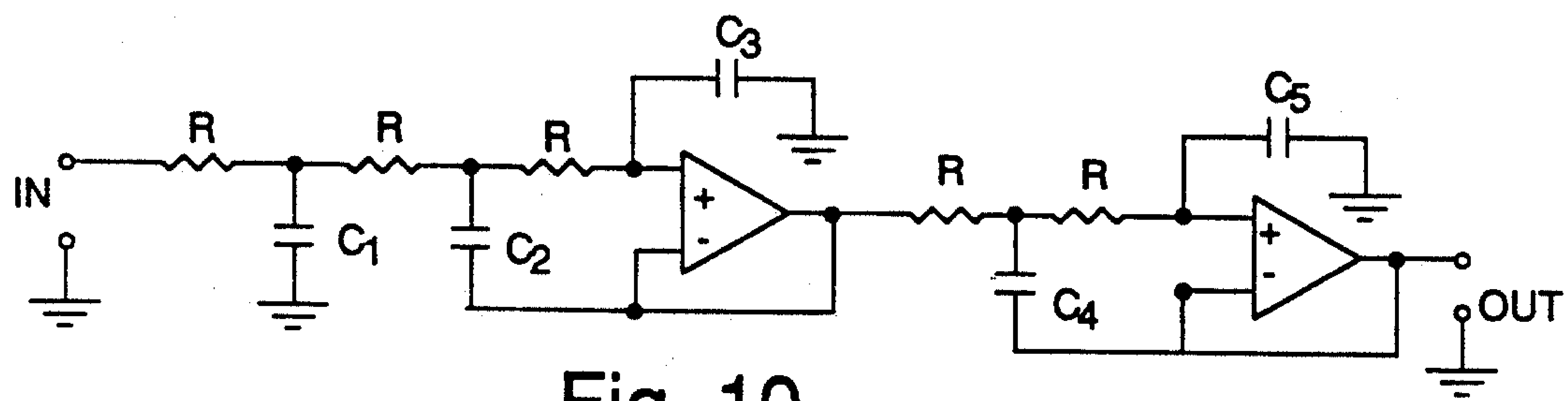

C3
C5
R
R
R
R
R
IN
C1
C2
C4
OUT

Fig. 10

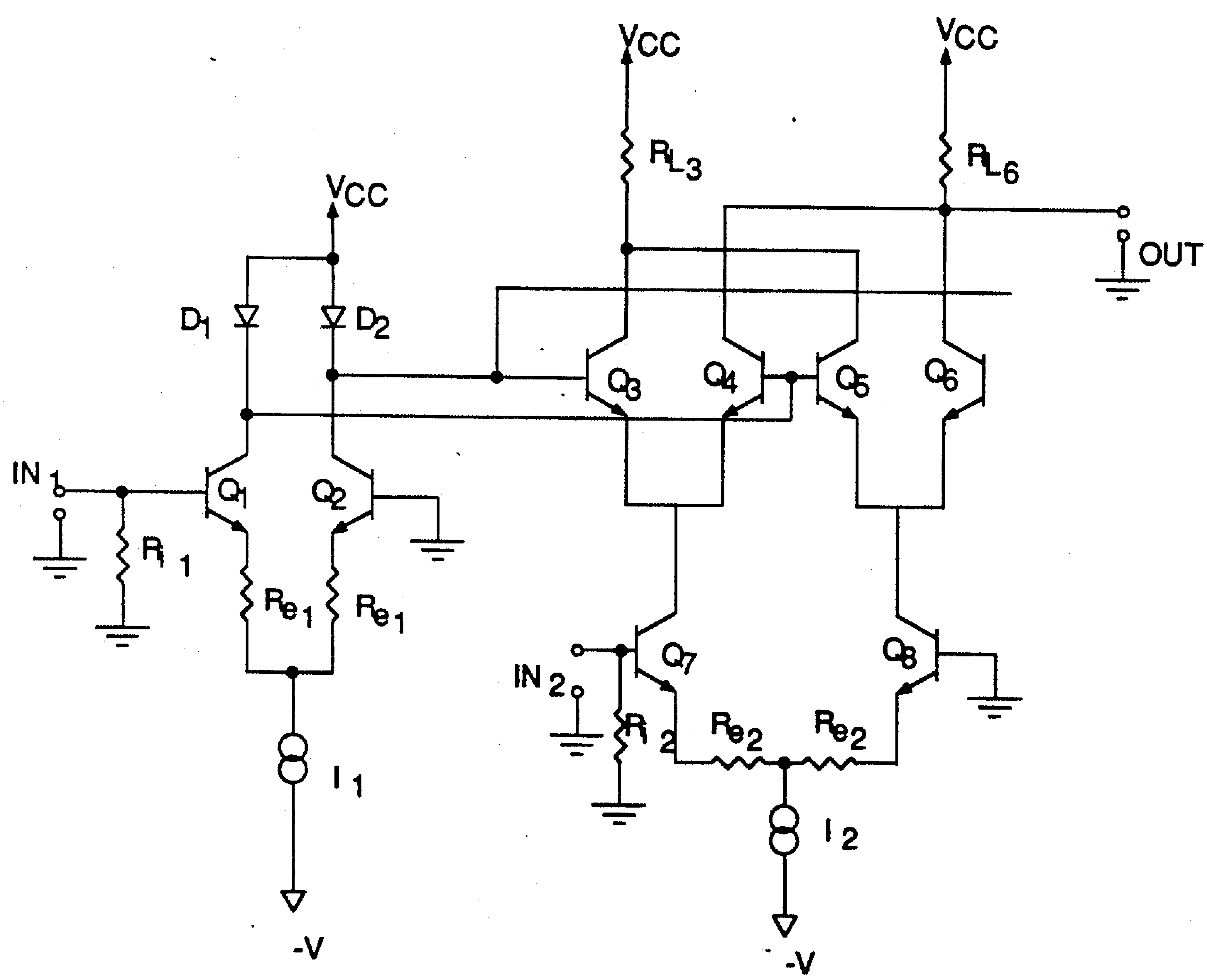

VCC
VCC
VCC
RL3
RL6
OUT
D1
D2
Q3
Q4
Q5
Q6
IN 1
Q1
Q2
R1 1
Re1
Re1
Q7
Q8
IN 2
R1 2
Re2
Re2
I 1
I 2
-V
-V

Fig. 11

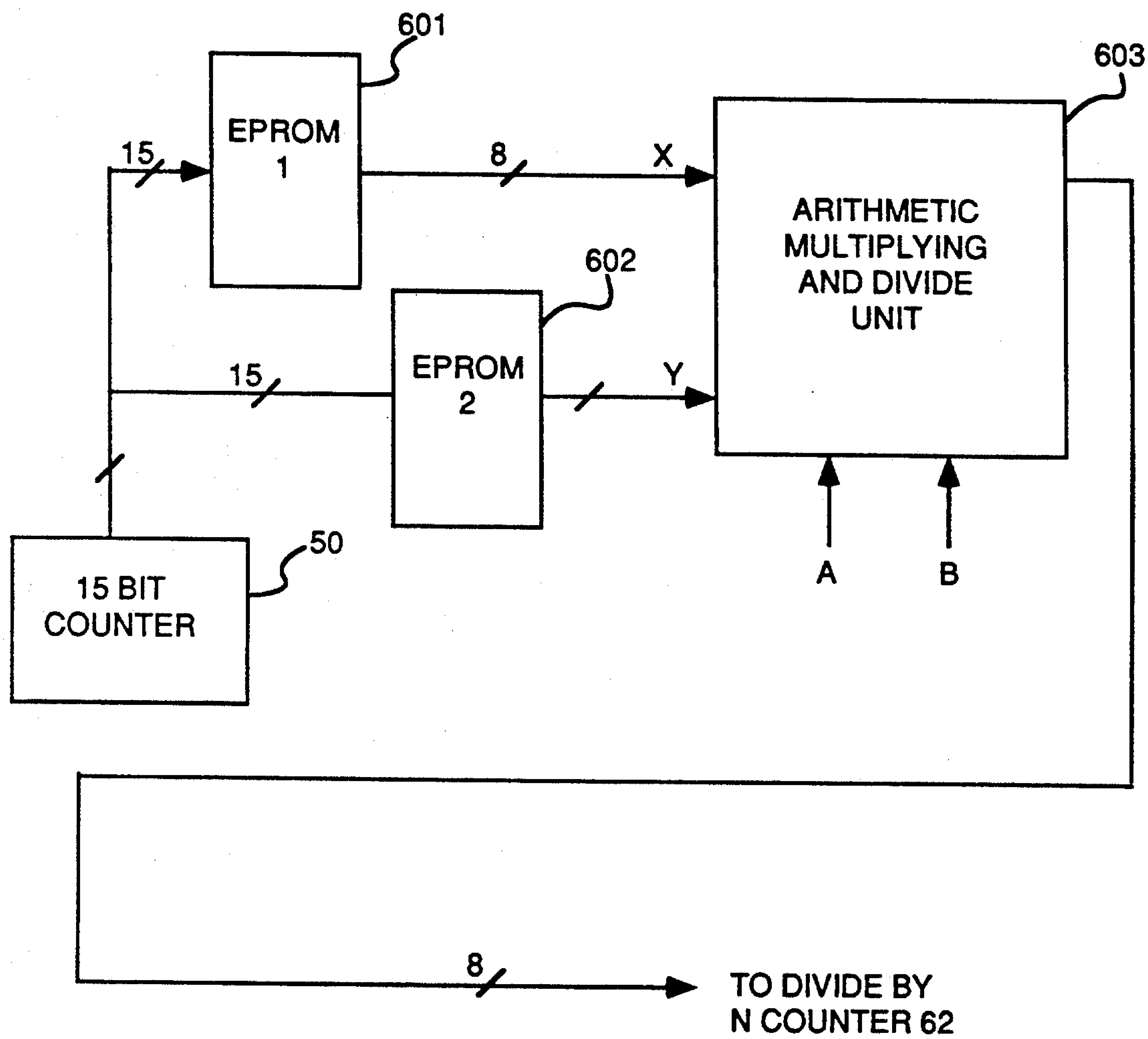

601
603
15
EPROM
1
8
X
ARITHMETIC
MULTIPLYING
AND DIVIDE
UNIT
602
EPROM
2
15
Y
50
15 BIT
COUNTER
A
B
8
TO DIVIDE BY
N COUNTER 62

Fig. 12

AUDIO SCRAMBLING SYSTEM USING IN-BAND CARRIER

BACKGROUND OF THE INVENTION

This invention relates to techniques for scrambling and descrambling audio information signals. More particularly, this invention relates to frequency shifting techniques for scrambling and descrambling such signals.

Various techniques have been employed in the past for the purpose of initially scrambling and subsequently descrambling audio information signals. One such technique is known as frequency inversion spectrum shifting, wherein the spectrum of original audio information signals is shifted by inversion so that those frequency portions originally lying at the lower end of the audio frequency band are shifted to the upper end while those portions originally lying near the upper end of the band are shifted to the lower end. Typically, this spectral inversion of the original audio information signals is performed prior to broadcasting or recording the signals either alone, or in combination with associated video signals, and this technique is described more fully in copending, commonly assigned U.S. patent application Ser. No. 366,575, filed Jun. 15, 1989 for "IMPROVED METHOD AND SYSTEM FOR SCRAMBLING AND DESCRAMBLING AUDIO INFORMATION SIGNALS", now U.S. Pat. No. 5,058,159 issued Oct. 15, 1992, the disclosure of which is hereby incorporated by reference. The major purpose of such scrambling is to prevent unauthorized reception or reproduction of the signals. As one commercial example, pre-recorded video cassettes can be rendered unintelligible by scrambling the audio information portion, so that only an authorized subscriber having a proper descrambling unit coupled to the television monitor/receiver can enjoy the program information by descrambling the audio portion.

A major disadvantage with known audio scrambling devices using frequency inversion spectrum shifting techniques is the introduction of frequency error upon recording and reproduction of the scrambled signals, which adversely affects the descrambling process. In particular, even if the scrambled audio signals are recorded on a cassette tape in a high quality VCR, the amount of frequency error introduced as wavering is at least ±1% at the carrier frequency for a typical unit. This frequency error introduces unwanted components into the recovered signals, resulting in garbled sounds which are annoying at best and unrecognizable at worst.

As a specific example, with a frequency spectrum inversion technique employed for audio signals having a bandwidth of 15 KHz, the typical minimum carrier frequency would be 1 KHz above the upper end of the band, or 16 KHz at base band. If a 700 Hz audio signal is scrambled using the 16 KHz carrier and then recorded on a tape in a quality VCR, the recorded signal will be 16 KHz-700 Hz±1%=15.3 KHz±153 Hz. Upon reproduction and descrambling using a carrier of the same frequency, the descrambled signal will be 16 KHz−[15.3 KHz±153 Hz]=700 Hz±153]Hz=700 Hz±21.9%. As will be appreciated by those skilled in the art, such a wide amount of wavering distortion will render the descrambled audio signals at least unpleasant if not unintelligible.

Another disadvantage encountered with frequency inversion techniques in audio signal processing results from the pre-emphasis signal processing normally encountered in broadcasting environments and in many recorders. More particularly, in a broadcasting application pre-emphasis is applied in an amount of +6 db per octave beginning at about 2 KHz. For audio signal processing, since the upper edge of the bandwidth (i.e., 15 KHz) lies in an area of high pre-emphasis, and since much of the audio energy upon frequency inversion is located at the upper edge, only relatively low signal levels can be appropriately input to a broadcast or recording system, which reduces the signal to-noise ratio by an undesirable amount.

SUMMARY OF THE INVENTION

The invention comprises a method and system for enabling scrambling of original audio information signals which substantially reduces the adverse effect of frequency variations in the reproduction of the scrambled signals to produce final audio signals of quality comparable to the original unscrambled signals, and which is highly compatible with existing pre-emphasis signal processing techniques employed in broadcasting and recording applications.

From a method standpoint, the invention broadly comprises frequency translating the original spectrum of audio information signals to produce scrambled audio information signals by generating a modulation carrier signal having a frequency lying within the frequency spectral range of the audio information signals, and single side band modulating the original information signals with the modulation carrier signal to translate the frequency of the original audio information signal in a given direction. Preferably, the frequency of the modulation carrier signal is varied during generation in a pseudo random fashion, particularly by sweeping the frequency of the modulation carrier signal between predetermined limits. The step of varying the frequency of the modulation carrier signal preferably includes the steps of initiating a frequency varying operation in response to a first control signal at a rate determined by a second control signal.

The step of single side band modulating preferably includes the steps of phase shifting the original audio information signals by 90°, phase shifting the modulation carrier signal by 90°, double side band mixing the original audio information signals with the 90° phase shifted version of the modulation carrier signal, double side band mixing the 90° phase shifted version of the original audio information signals with the modulation carrier signal, and summing the signals resulting from the double side band mixing steps to produce the desired scrambled audio signals.

The scrambled signals are later descrambled by generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal, and single side band modulating the scrambled audio signals with the descrambling modulation carrier signal to recover the original audio signals. During descrambling, the step of single side band modulating includes the steps of phase shifting the scrambled audio signals by 90°, phase shifting the descrambling modulation carrier signal by 90°, double side band mixing the scrambled audio signals with the descrambling modulation carrier signal, double side band mixing the 90° phase shifted version of the scrambled audio signals with the 90° phase shifted version of the descrambled modulation carrier signal, and summing the signals resulting from the double side band mixing steps to remove the scrambling single side band signal component.

From a system standpoint, the invention broadly comprises means for generating a modulation carrier signal at a frequency lying within the original frequency spectral range of audio information signals, and processing means having a first input coupled to the generating means and a second input for receiving the audio information signals for producing scrambled audio signals resulting from the single side band mixing of the modulaticn carrier signal and the audio information signals. The generating means preferably includes means for varying the frequency of the modulation carrier signal in a pseudo random fashion, preferably by sweeping the frequency of the modulation carrier signal between predetermined limits. The generating means further preferably includes means responsive to a first control signal for initiating the varying means and means responsive to a second control signal for establishing the varying rate.

The processing means preferably includes first phase shifting means for phase shifting the modulation carrier signal by 90°, second phase shifting means for phase shifting the audio information signals by 90°, first double side band mixing means coupled to the first phase shifting means for mixing the audio information signals and the 90° phase shifted version of the modulation carrier signal, second double side band mixing means coupled to the second phase shifting means for mixing the 90° phase shifted version of the audio information signals with the modulation carrier signal, and means coupled to the first and second double side band mixing means for summing the output signals therefrom to provide the desired scrambled audio signals.

The descrambling system includes means for generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal, and processing means having a first input coupled to the generating means and a second input for receiving the scrambled audio information signals for removing the scrambled single side band signal component therefrom to recover the original audio information signals. The generating means preferably includes means responsive to the first control signal for initiating the varying means and means responsive to the second control signal for establishing the varying rate.

The descrambler processing means preferably includes first phase shifting means for phase shifting the scrambled audio signals by 90°, second phase shifting means for phase shifting the descrambling modulation carrier signal by 90°, first double side band mixing means for mixing the scrambled audio signals with the descrambling modulation carrier signal, second double side band mixing means coupled to the first and second phase shifting means for mixing the 90° phase shifted version of the scrambled audio signals with the 90° phase shifted version of the descrambling modulation carrier signal, and means coupled to the first and second double side band mixing means for summing the output signals therefrom to remove the scrambling single side band signal component.

The invention further comprises a system for generating the variable frequency sine wave carrier signal in response to a start signal and a rate signal, the carrier signal having frequencies lying within a predetermined spectral frequency limit, and the system including first settable counter means having a clock input for receiving a first clock signal, a count input for receiving modulus value signals for establishing the counter modulus N, and an output terminal for manifesting a binary output signal having a frequency determined by the modulus N and the first clock signal; modulus generating means having a control input for receiving the start signal, a clock input for receiving a second clock signal, and an output coupled to the count input of the first settable counter means for generating a succession of modulus values in response to receipt of a start signal and the second clock signal; and means having an input coupled to the output terminal of the first settable counter means for converting the binary output signals therefrom to analog sine signals of variable frequency.

The modulus generating means preferably includes a second counter means having an input serving the clock input of the modulus generating means and an output, and memory means for storing the modulus values, the memory means having address inputs coupled to the output of the second counter means. The memory means includes a first memory device for storing a first plurality of modulus determining values, a second memory device for storing a second plurality of modulus determining values, and processing means for receiving modulus determining values from the first and second memory devices for generating the modulus value signals for the first settable counter means.

The system further includes a second clock generating means, the second clock generating means including an oscillator and a second settable counter means having a clock input coupled to the oscillator, a count input terminal means for receiving the rate signal, and an output terminal means coupled to the clock input of the modulus generating means, the output of the second settable counter means having a frequency determined by the value of the rate signal. The rate signal may be either periodic, or non-periodic: if non-periodic, the rate signal is preferably pseudo random.

The converting means preferably includes a first low pass filter means for smoothing the binary output signals from the first settable counter means; means for generating a sine wave signal having a frequency different from the frequency of the signals output from the first low pass filter means; mixer means having a first input coupled to the output of the first low pass filter means, a second input coupled to the output of the sine wave signal generating means, and an output; and second low pass filter means having an input coupled to the output of the mixer means and an output for passing signals having frequencies lying within the predetermined spectral frequency limit.

For a fuller understand of the nature and advantages of the invention, reference should be made to the ensuing detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a block diagram illustrating scrambling of the audio portion of composite video signals;

FIG. 1B is a block diagram illustrating descrambling of previously scrambled signals;

FIG. 2 is a schematic diagram illustrating the modulation circuitry for scrambling the original audio signals;

FIG. 3A is a frequency spectrum diagram illustrating the relationship between the modulation carrier and the original audio pass band;

FIG. 3B is a diagram similar to FIG. 3A illustrating the frequency translation effected according to the invention;

FIG. 4 is a schematic diagram illustrating the demodulation circuitry for descrambling the scrambled audio signals;

FIG. 5 is a schematic diagram illustrating the modulation carrier signal generator used in the scrambling/descrambling units;

FIGS. 6A–6D are timing diagrams illustrating the modulation carrier signal generation process;

FIG. 7 is a logic diagram illustrating the K counter of the generator of FIG. 5;

FIG. 8 is a logic diagram illustrating the divide by N counter of the generator of FIG. 5;

FIG. 9 is a circuit diagram of a single stage of the wide band phase shifter used in the modulation circuitry of FIG. 2;

FIG. 10 is a circuit diagram illustrating the low pass filters used in the generator of FIG. 5;

FIG. 11 is a circuit diagram showing the double side band mixer used in the circuitry of FIG. 2; and

FIG. 12 is a schematic diagram illustrating an alternate embodiment of the modulus generator for the divide by N counter of FIG. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to the drawings, FIG. 1A illustrates use of the invention to scramble the audio portion of video program signals prior to recording both the video and audio portions onto a video cassette. As seen in this Fig., the video program information signals, including coded control signals termed ACLK, A0, and A1 (described below) are coupled directly to the video input of a conventional video cassette recorder 12. The audio portion, on the other hand, is coupled to the audio input of the scrambler unit 14 in which the audio signals are scrambled in the manner described below. The control signals ACLK, A0 and A1 are also coupled to a control input portion of scrambler unit 14. The scrambled audio output signals from scrambling unit 14 are then coupled to the audio input terminal of video cassette recorder unit 12. FIG. 1B illustrates the playback mode for the video and scrambled audio signals prepared in the FIG. 1A system. As seen in FIG. 1B, the video program information appearing at the video output terminal of the VCR unit 12 is coupled directly through a descrambler unit 16 to the associated follow-on electronics (i.e., the television monitor 15). The scrambled audio signals, in contrast, are coupled to the input of the descrambler unit 16. Also, as suggested by the broken line and legends within unit 16, the ACLK, A0 and A1 signal portions of the video output from VCR unit 12 are separated and coupled to the control input portion of descrambler unit 16 for descrambling in the manner described below. The output from the descrambler unit 16 is the audio program portion, now unscrambled, which is amplified by amplifier 17 and coupled to speaker 18.

The scrambling technique employed in the preferred embodiment of the invention is frequency shifting the original audio information signals by upper single side band frequency translation; the descrambling technique employed is lower single side band frequency translation to restore the original audio band frequencies. With reference to the scrambling technique, the original audio information signals are processed by single side band modulation using a modulation carrier having a frequency lying within the original audio information signal band so that all portions of the original audio information signals are shifted up by an amount dependent upon the frequency of the modulation carrier. In addition, the frequency of the modulation carrier signal is varied in a unique manner so that the absolute value of a given frequency in the original audio information signal spectrum changes during scrambling in an unpredictable manner. As a result, the scrambled audio signals, if applied to conventional audio processing circuitry of a receiver/monitor, are so garbled as to be unusable.

The aperiodic variation of the modulation carrier frequency is initiated by an aperiodic timing signal ACLK, which is generated in a pseudo random fashion and which initiates a monotonic sweeping of the modulation carrier from a starting frequency to an ending frequency. The rate at which the frequency is varied is determined by the A0 and A1 binary rate control signals, which are generated in accordance with any suitable scrambling scheme. Thus, the ACLK signal controls the start of the modulation carrier frequency variation, while A0 and A1 control the rate of change of the modulation carrier frequency. The ACLK, A0 and A1 signals are encoded in the vertical interval of the video frames and recorded along with the scrambled audio signals for later reproduction and use during the descrambling operation.

FIG. 2 illustrates that portion of the scrambler unit 14 of FIG. 1A in which the original audio frequency signals are shifted upwards in frequency by single side band modulation using a modulation carrier signal having a frequency lying within the original audio signal frequency spectrum. As seen in this Fig., the original audio program information signals having frequencies ωb ($=2\pi f$) lying within a typical audio frequency spectrum of 50 Hz to 15 KHz are coupled to the input of a first wide band phase shifter 21 which provides as output signals the original input signals and a phase shifted version of the original input signals, with the phase difference being a constant 90°. The 0° output from phase shifter 21 is coupled as a first input to a first double side band mixer 23, while the 90° phase shifted version of the original input signals is coupled as a first input of a second double side band mixer 24. A modulation carrier signal source 25 preferably of the type illustrated in FIGS. 5–8, 10 and 11 generate a modulation carrier signal of frequencies ωc lying in the preferred embodiment) from about 1.4 KHz to about 3 KHz. The modulation carrier signal output from source 25 is coupled to a second wide band phase shifter 26 identical to wide band phase shifter 21, the first stage of which is illustrated in FIG. 9. The 0° output from wide band phase band mixer 24, while the 90° version of the modulation carrier signal from wide band phase shifter 26 is coupled as the second input to double side band mixer 23. The modulation product outputs from mixers 23, 24 are coupled through a summing amplifier 28, the output of which comprises the scrambled version of the original audio input signals, which are coupled to the VCR unit 12 shown in FIG. 1A. The double side band mixers 23, 24 preferably have the configuration shown in FIG. 11.

Since the output of mixer 23 is $[\sin \omega bt]\times[\cos \omega ct]$, and the output of mixer 24 is $[\cos \omega bt]\times[\sin \omega ct]$, where ωb are the frequencies in the original audio band and ωc are the carrier frequencies, the output of summing amplifier 28 is the sum of the two product terms which simply equals sin [ωb+ωc]t. It should be noted that the use of two double side band mixers to generate the upper side band frequency translation is necessary due to the fact that the modulation carrier frequency lies within the audio pass band. This is illustrated in FIG. 3A, which is a plot of signal amplitude v versus frequency f for the audio pass band showing the cut-off at about 15 KHz and a single carrier frequency of about 1.5 KHz. If only one double side band mixer were used, the lower side band would interfere with the upper side band because the difference frequency (i.e., the lower side band) is beat by a frequency lower than the upper end of the audio band. This mixing produces lower side band frequencies from D.C. to 13.5 KHz. Thus, from 1.5 KHz to 13.5 KHz both the upper and lower side bands mix, and this normally adverse effect is avoided by the use of the two double side band mixers **23, 24**.

FIG. 3B illustrates the translation effect on the original audio program frequencies of the modulation circuitry of FIG. 2. The original audio signals have been translated upperwardly by an amount equal to the carrier frequency (i.e., the entire spectrum has been shifted upward by an amount ωc). As will be understood by those skilled in the art, if ωc varies in value with time, the real time effect of the modulation is an upward shift from base band by an amount equal to the instantaneous value of ωc.

FIG. **4** illustrates the demodulation circuitry used in the descrambler unit **16** of FIG. **1**B. As seen in FIG. **4**, descrambling of the scrambled audio supplied from the VCR **12** at frequency ωb' is accomplished by essentially identical circuitry configured as a lower single side band mixer. In particular, the 0° output from the second wide band phase shifter **26** is coupled as the second input of double side band mixer **23**, while the 90° output from second wide band phase shifter **26** is coupled as the second input of double side band mixer **24** (compare FIG. 2 in which the outputs of the second wide band phase shifter **26** are coupled in reverse order to mixers **23, 24**). The output of summing amplifier **28** in the descrambler unit of FIG. **4** is [sin ωb't]×[sin ωct]+[cos ωb't]×[cos ωct]=cos ∂ωb'−ωc]t where ωb'=ωb+ωc. Thus, the output=cos [ωb+ωc−ωc]t=cos ωbt. The use of a single side band mixer is essential for descrambling the scrambled audio information. If a mixer, such as a double side band mixer, is used, the descrambled audio would result in large amounts of distortion due to the fact that the lower and upper side bands interfere within the audio base band spectrum. Only the use of a single side band mixer will yield an undistorted descrambled output.

It should further be noted that the modulation and demodulation carrier signals should be as close as possible to constant amplitude pure sine wave sources. If either carrier is not a pure sine wave, intermodulation distortion will occur during descrambling. For example, assume that the carrier ωc is 1 KHz with 10% third harmonic distortion at 3 KHz. If the audio program signal has a frequency of 500 Hz, then the output of the scrambler **14** will be 1500 Hz (1 KHz+500 Hz) and 3500 Hz (3 KHz+500 Hz). In this example, even if the descrambling modulation frequency is a pure sine wave at 1 KHz, the descrambled tones will be 1500 Hz-1 KHz=500 Hz and 3500 Hz−1 KHz=2500 Hz, the latter comprising an undesired distortion product. This distortion is exacerbated if the descrambling modulation carrier is the same as the scrambling modulation carrier, since the descrambled output from summing amplifier **28** will now be 1500 Hz−1 KHz, 1500 Hz−3 KHz, 3500 Hz−1 KHz, and 3500 Hz−3 KHz, which yields 500 Hz, 1500 Hz, 2500 Hz, and 500 Hz. In this case, the signals at 1500 Hz and 2500 Hz are the extraneous distortion products. As a guideline, for purposes of this invention a pure sine wave is defined as one having less than 0.1 % harmonic distortion (i.e., second or higher order harmonic components of amplitude less than 0.1 % of the carrier frequency). In addition, the amplitude of the modulation carrier signal should be substantially constant.

The improvement afforded by the simple translation modulation system described above over an inverted side band modulation system may now be explored. For the system described above, and assuming a modulation carrier frequency of 500 Hz and an audio signal of 700 Hz, the output of the scrambler unit **14** (FIG. **1A**) will be 500 Hz+700 Hz=1200 Hz. If this signal is recorded on a VCR which has ±1% variation, the playback signal will be 1200 Hz±1%=1200 Hz±12 Hz. The descrambled output will then be 1200 Hz±12 Hz−500 Hz=700 Hz±12 Hz=700 Hz±1.7%.

With an inverted side band system operating on an audio pass band having a 15 KHz bandwidth, the carrier frequency must be at least 16 KHz to be marginally outside the upper bandwidth. For the same audio signal as in the example noted above, the scrambled output would be 1600 Hz−700 Hz=15.3 KHz. When recorded and played back on the same VCR with a ±1% speed variation, the scrambled tone during playback is 15.3 KHz±1%=15.3 KHz±153 Hz. The corresponding descrambled output is 1600 KHz−15.3 KHz±153 Hz=700 Hz±153 Hz=700 Hz±21.9%. The improvement in the frequency Variation distortion performance afforded by the invention is apparent.

The harmonic distortion performance is also enhanced according to the invention over the inverted side band system due to the high frequency head room crashing frequently encountered in the inverted side band system. In particular, the signal level of an audio signal to be broadcast or recorded is typically pre-emphasized prior to recording or broadcasting beyond about 2000 Hz in the amount of about 6 db per octave. As a consequence, at 15 KHz the maximum permissible level of a input signal into a broadcast system is about −17 db. Similar performance is obtained with analog tape recorders. With an inverted side band system, the frequency spectrum of the original signals is inverted: i.e., those frequency portions originally lying at the lower end of the audio frequency band are shifted to the upper end while those portions originally lying at the upper end of the band are shifted to the lower end. With such a system, since most of the energy is at about 15 KHz, the inverted side band method only allows about −17 db of input over the entire audio bandwidth into a broadcast system. With the frequency translation technique according to the invention, however, the maximum input level is still about 0 db (i.e., the same level as that in a system without inversion), since the translated spectrum is almost identical with the spectrum of the base band. For example, for voice frequencies (typically in the range from 300 Hz-3 KHz), a frequency translation of 1 KHz according to the invention yields a spectrum of 1300 Hz to 4 KHz, while the prior art frequency inversion technique yields a spectrum of 14.7 KHz to 12 KHz. Thus, using the prior art inverted side band technique, with a broadcast or analog tape deck system the input will have to be at −17 db whereas with the translation system according to the invention the input can be at −6 db. Consequently, the translation system according to the invention improves the signal-to-noise ratio by as much as 11 db.

As noted above, the reason for scrambling the audio signals is to limit enjoyment of the program information represented by the audio signals to authorized subscribers. The security of the simple translation system just described is greatly enhanced by varying the frequency of the modulation carrier signal. FIGS. **5–8**, **10** and **11** illustrate the preferred embodiment for accomplishing pseudo random carrier frequency variation according to the invention in both the scrambler unit **14** and the descrambler unit **16**. With reference to FIG. **5**, a 15 bit counter **50** has a start input terminal **51** to which the ACLK control signal is coupled and a clock input terminal **52** to which the counter clock is supplied. The counter clock is supplied from a counter **53** termed the ÷ K counter having a pair of preset inputs **54**, **55** to which the **A0**, **A1** rate control signals are supplied. The clock input terminal **56** of counter **53** is supplied with a 1 MHz clock signal from a source **57**. The state outputs of 15 bit counter **50** are coupled as address inputs to an EPROM memory unit **60**. Counter **50** is configured to continuously count down after starting from a maximum value to a minimum value, automatically reset to the maximum count state, and await the next start pulse ACLK. The **8** bit output from EPROM **60** is coupled to the preset inputs of a ÷ by N counter **62**. Counter **62** has a clock input **63** which is supplied with a 15 MHz clock signal from a crystal oscillator source **64**. The output of ÷ by N counter **62**, in the preferred embodiment, is a 6 KHz–7.6 KHz square wave, which is coupled to the input of a first low pass filter **66**, the output of which is coupled to a first input of a mixer **67**. The other input to mixer **67** is the output of a 9 KHz sine wave source **68**. The output of mixer **67** is coupled to the input of a low pass filter **69**, which is substantially identical in structure and function to the filter **66**. The output of low pass filter **69** is a variable frequency sine wave whose frequency ranges from 1400 Hz to 3000 Hz. The configuration of low pass filters **66**, **69** in the preferred embodiment is illustrated in FIG. **10**.

In operation, counter **50** is enabled to begin counting from an initial count by the leading edge of an ACLK signal (FIG. **6B**). The rate at which counter **50** is decremented is determined by the clock input on terminal **52** supplied by ÷ by K counter **53**. Although the clock input present on input terminal **56** to the ÷ by K counter **53** is a constant frequency (1 MHz) clock signal from source **57**, the value of K and thus the frequency of the output clock from K counter **53** is dependent upon the values of **A0**, **A1** on the control input terminals **54**, **55**. ACLK, **A0** and **A1** signals are all generated initially at the scrambling site and are conveyed along with the scrambled audio information to the descrambling site. In the video system illustrated in FIGS. **1A** and **1B**, control signals ACLK, **A0** and **A1** are all embedded in appropriate portions of the vertical interval of the video signals in any appropriate fashion.

As counter **50** is clocked by the clock signal from ÷ by K counter **53**, the values stored in EPROM **60** are read out at a rate determined by the rate at which counter **50** is being clocked. In the preferred embodiment, EPROM **60** is completely read within a range of about 1.5 to 10 seconds. For each value output from EPROM **60**, the ÷ by N counter **62** generates a square wave at a specific frequency within the range of 6 KHz–7.6 KHz, depending on the value of N (the counter modulus) specified by the output of EPROM **60**. The square wave output from counter **62** is smoothed in low pass filter **66** to provide a relatively pure sine wave whose instantaneous frequency is in the range from 6 KHz–7.6 KHz. This signal is mixed in mixer **67** with the 9 KHz source **68**, and the output from the mixer **67** is low pass filtered by filter **69** to provide a constant amplitude pure sine wave whose instantaneous frequency lies within the range of 1.4 KHz–3.0 KHz.

The operation of the FIG. **5** circuit is illustrated in FIGS. **6A–6D**. In particular, FIG. **6A** illustrates the state of the counter **50** output, while FIGS. **6A** and **6B** show the relationship between the ACLK signal and the start of the decrementing of counter **50**. Note that the distance between successive leading edges of the ACLK signal varies in a random or pseudo random fashion and is not constant. Thus, for the first ACLK leading edge, counter **50** commences counting from a maximum count value in a linear fashion down to the minimum value, automatically resets to the maximum count and waits for the leading edge of the next ACLK pulse signal. When this occurs, the counter again commences counting down from the maximum to the minimum value, resets to the maximum state, etc.

The slope of the counter **50** output trace and thus the countdown rate is determined by the value of **A0** and **A1** when counter **50** is started by the leading edge of ACLK signal. The relationship between the four possible **A0**, **A1** values (for the two bit control signal version illustrated) and the output frequency of the ÷ by K counter **53** is illustrated in FIG. **6C**. As seen in this Fig., which plots frequency of the counter **50** input clock versus time, the first pair of values of **A0**=0, **A1**=1 provides a first count frequency producing the counter **50** countdown slope depicted in the region of FIG. **6A** after the leading edge of the first ACLK pulse. Similarly, the second pair of values of **A0**=1, **A1**=1 provides a different counter **50** clock frequency (the highest frequency in the example shown) producing the counter **50** countdown slope in the region after the leading edge of the second ACLK pulse. Similarly, **A0**=0, **A1**=0 provides the lowest counter **50** clock frequency and the slope depicted in the region after the leading edge of the third ACLK pulse.

FIG. **6D** shows the effect on the carrier signal output from low pass filter **69** of the combined ACLK, **A0** and **A1** signals. During the count period commencing with the leading edge of the first ACLK pulse the frequency of the sine wave output from filter **69** sweeps between the minimum and maximum frequencies (1400 Hz–3000 Hz) at a first linear rate, starting at some initial value determined by the first modulus N output value from EPROM **60**. After the counter **50** has counted down to the minimum value and is automatically reset, the output frequency stabilizes at the initial value during interim period designated X_1, which is the waiting period between the end of the countdown of counter **50** and the arrival of the leading edge of the next ACLK pulse. Upon arrival of the second ACLK pulse, counter **50** is decremented at the maximum rate (specified by **A0**=1, **A1**=1) and the frequency of the sine wave output from filter **69** varies between the limits in a linear fashion swept at a higher frequency. When counter **50** counts down and is reset, the sine wave output remains at the constant mid-value depicted during interim period X_2 until the arrival of the leading edge of the next ACLK pulse. The operation continues as already described for each successive appearance of the A0, A1 values and the leading edge of the ACLK pulse.

In the scrambling operation, the ACLK, A0, and A1 signals are all provided to scramble unit **14** from a suitable source. In the FIG. **6A–6D** embodiment, the repetition rate of successive ACLK signals is preferably varied in an unpredictable manner, using any known pseudo random counting device; while the values of A0, A1 are also pseudo randomly generated. In addition, the spacing between successive ACLK pulses and the rate values A0, A1 are selected such that counter **50** is permitted to decrement to the minimum value before the start of the next counter **50** cycle, so that the frequency variation is not subject to a sudden discontinuity which could result from a premature resetting of counter **50** and which is undesirable.

In the descrambling operation, the ACLK, A0, A1 signals must be provided to the descrambler unit **16** along with the scrambled audio signals so that the descrambling modulation carrier signal is generated in such a manner as to match the scrambling modulation carrier signal. This provision of the control signals can be accomplished in any suitable manner known to those skilled in the art. In the example shown in FIGS. **1A** and **1B** utilizing associated video signals, the ACLK, A0 and A1 signals can be inserted into the vertical blanking intervals of selected video fields and detected using conventional detection circuitry.

Other combinations of ACLK, A0 and A1 start and rate signals may be employed. For example, the repetition rate of ACLK may be fixed at some periodic value, and the values of A0, A1 or both may be changed randomly during the time period between successive ACLK pulses. The effect is to vary the clock **2** input on terminal **52** of counter **50** in a pseudo random manner, which causes a similar effect at the output of counter **50**. For optimum operation, the relative values of the ACLK repetition rate and the rates specified by A0, A1 should be selected so that counter **50** is decremented to the final value (by the clock **2** signal) prior to reset by the succeeding ACLK pulse to avoid a sharp discontinuity in the frequency of the output of counter **62**.

FIG. **9** illustrates one stage of a pair of phase shifters providing two constant amplitude phase shifters yielding a pair of net outputs of 0° and 90°. All of the R resistances have the same value. However, the values of R_1, C_1 and R_2, C_2 are selected to provide the 90° difference between the two outputs $VOUT_1$ and $VOUT_2$. To increase the range of the upper and lower frequencies, pairs of phase shifter sections illustrated in FIG. **9** are added in cascade to construct phase shifters **21**, **26** of the scrambler and descrambler units.

With reference to FIG. **11**, which illustrates mixers **23**, **24** of the scrambler and descrambler units, resistances Re_1 provide local feedback to linearize the Q_1 and Q_2 collector current versus the input voltage IN_1 at the bases of Q_1, Q_2 Diodes D_1 and D_2 predistort the driving voltage into Q_3–Q_6 such that the transfer function from IN_1 to the output voltage at RL_6 is linear. Voltage IN_2 is linearized for Q_7 and Q_8 collector current via both resistances Re_2. Due to the push/pull arrangement of the collector currents of Q_7 and Q_8 modulating the amplifier pairs of Q_3, Q_4 and Q_5, Q_6, a linear relationship is provided between IN_2 and the output signal. In general, the output signal equals $K \times IN_1 \times IN_2$, where K is a constant.

FIG. **12** illustrates an alternate embodiment of the invention which provides enhanced security to the process for generating the modulus N frequency specifying signals for counter **62**. As seen in FIG. **12**, the single EPROM memory unit **60** is replaced by a pair of EPROM memory units **601**, **602**, each having multi-bit address input terminals coupled to the output of counter **50**. Each EPROM memory unit **601**, **602** stores a plurality of 8 bit modulus determining values which are individually addressed by the output of counter **50** and coupled to the paired inputs of an arithmetic logic unit **603**. Also coupled to the input of arithmetic logic unit **603** are a pair of numerical coefficient values designated a, b, which are multi-bit (i.e., 4 bit) randomly generated numbers. The output of ALU **603** is coupled to the address input of divide by N counter **62**. The alternate embodiment shown in FIG. **12** adds enhanced security by generating each modulus specifying value N from a pair of multi-bit (8 bit) values stored in the memory units **601**, **602** and the two random numbers a, b, which are used in any desired algorithmic manner. For example, the output from ALU **603** may be simply the linear combination $aX+bY$, where X and Y are the output values from memory devices **601**, **602**; similarly, the coefficient a, b may additionally be used as a combinatorial divisor for the values X, Y, or in any other suitable fashion.

As will now be apparent, the invention provides scrambling and descrambling of audio information signals which results in the recovery of the original audio information signals in a faithful manner. The signals are recovered with minimal fluctuations in phase and frequency introduced by the electromechanical recording apparatus used to record and reproduce the signals; and the recovered signals are relatively unaffected (as compared to frequency inversion scrambling) by the limited high frequency head room found in broadcast pre-emphasis and record equalization systems. At the same time, the audio signals are scrambled in a very secure fashion by use of the pseudo random varying modulation carrier, while requiring a substantially narrower bandwidth than other audio scrambling techniques, in particular, digital scrambling systems. Further, since the entire scrambling and descrambling signal processing occurs in the analog domain, relatively low distortion is introduced to original audio input signals having a relatively low level, as opposed to digital systems which can completely corrupt low level input signals.

While the above provides a full and complete disclosure of the preferred embodiment of the invention, various modifications, alternate constructions and equivalents will appear to those skilled in the art. For example, while specific frequencies have been illustrated for the modulation carrier signal, other values may be more suitable in a given application. Also, the security afforded by the pseudo random varying modulation carrier frequency may be enhanced by adding passwords, additional control signals supplemental to **A0**, **A1** and other techniques known to those skilled in the art. Therefore, the above descriptions and illustrations should not be construed as limiting the invention which is defined by the appended claims.

What is claimed is:

1. A method of scrambling audio information signals having frequency components lying within an original frequency spectral range of about 50 Hz to about 15 kHz, said method comprising the steps of:

(a) generating a modulation carrier signal at a frequency lying within the original frequency spectral range, and

(b) single side band modulating the original audio information signals with the modulation carrier signal from step (a) to translate the frequency of said original audio information signals in a given direction, the resulting signals having a frequency greater than the frequency of the carrier signal.

2. The method of claim **1** wherein said step (a) of generating includes the step of varying the frequency of the modulation carrier signal.

3. The method of claim **2** wherein said step of varying includes the step of continuously sweeping the frequency of the modulation carrier signal between predetermined limits.

4. The method of claim **2** wherein said step of varying is performed in a pseudo random fashion.

5. The method of claim **2** wherein said step of varying includes the steps of initiating a frequency varying operation in response to a first control signal (**A0**, **A1**) at a rate determined by a second control signal (**A0**, **A1**).

6. The method of claim **1** wherein said step (b) of single side band modulating includes the steps of phase shifting the original audio information signals by 90°, phase shifting the modulation carrier signal by 90°, double side band mixing the original audio information signals with the 90° phase shifted version of the modulation carrier signal, double side band mixing the 90° phase shifted version of the original audio information signals with the modulation carrier signal, and summing the signals resulting from the double side band mixing steps to produce the desired scrambled audio signals.

7. A method of descrambling audio information signals previously scrambled by generating a scrambling modulation carrier signal at a frequency lying within the frequency spectral range of original audio information signals of about 50 Hz to about 15 kHz and single side band modulating the original audio information signals with the modulation carrier signal to produce scrambled audio signals containing a frequency translated version of the original audio information signals, said descrambling method comprising the steps of:

(a) generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal; and

(b) single side band modulating the scrambled audio signals with the descrambling modulation carrier signal to remove the scrambling single side band signal component and recover the original audio information signals, said recovered audio information signals having a maximum frequency greater than the frequency of the carrier signal.

8. The method of claim **7** wherein the scrambled audio signals have a variable frequency component contributed by the scrambling modulation carrier signal, and wherein said step (a) of generating includes the step of varying the frequency of the descrambling modulation carrier signal in a substantially identical manner as the variation in the scrambled audio signals.

9. The method of claim **8** wherein said variable frequency component of said scrambled audio signals comprises a swept frequency, and wherein said step of varying includes the step of continuously sweeping the frequency of said descrambling modulation carrier signal in substantially the same manner.

10. The method of claim **9** wherein said swept frequency is pseudo random, and wherein said step of sweeping is performed in substantially the same pseudo random manner.

11. The method of claim **8** wherein said scrambled audio signals include associated first control signals (**A0**, **A1**) specifying the start of a frequency varying operation and second associated control signals (**A0**, **A1**) specifying the frequency varying rate; and wherein said step of varying includes the steps of initiating a frequency varying operation in response to said first control signals at a rate determined by said second control signals.

12. The method of claim **7** wherein said step (b) of single side band modulating includes the steps of phase shifting the scrambled audio signals by 90°, phase shifting the descrambling modulation carrier signal by 90°, double side band mixing the scrambled audio signals with the descrambling modulation carrier signal, double side band mixing the 90° phase shifted version of the scrambled audio signals with the 90° phase shifted version of the descrambling modulation carrier signal, and summing the signals resulting from the double side band mixing steps to remove the scrambling single side band signal component.

13. A system for scrambling audio information signals having frequency components lying within an original frequency spectral range of about 50 Hz to about 15 kHz, said system comprising:

means for generating a modulation carrier frequency lying within the original frequency spectral range; and

single side band processing means having a first input coupled to said generating means and a second input for receiving said audio information signals for producing scrambled audio signals resulting from the single side band mixing of said modulation carrier signal and said audio information signals, said scrambled audio signals having a frequency greater than the frequency of said carrier signal.

14. The system of claim **13** wherein said generating means includes means for varying the frequency of said modulation carrier signal.

15. The system of claim **14** wherein said varying means includes means for continuously sweeping the frequency of said modulation carrier signal between predetermined limits.

16. The invention of claim **14** wherein said generating means includes means responsive to a first control signal (**A0**, **A1**) for initiating said varying means and means responsive to a second control signal (**A0**, **A1**) for establishing the varying rate.

17. The invention of claim **13** wherein said processing means includes first phase shifting means for phase shifting said modulation carrier signal by 90°, second phase shifting means for phase shifting said audio information signals by 90°, first double side band mixing means coupled to said first phase shifting means for mixing said audio information signals and the 90° phase shifted version of the modulation carrier signal, second double side band mixing means coupled to said second phase shifting means for mixing the 90° phase shifted version of the audio information signals with the modulation carrier signal, and means coupled to said first and second double side band mixing means for summing the output signals therefrom to provide the desired scrambled audio signals.

18. A system for descrambling audio information signals previously scrambled by generating a scrambling modulation carrier signal at a frequency lying within the frequency spectral range of original audio information signals of about 50 Hz to about 15 kHz and single side band modulating the original audio information signals with the modulation carrier signal to produce scrambled audio signals containing a frequency translated version of the original audio information signals, said system comprising:

means for generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal; and

single side band processing means having a first input coupled to said generating means and a second input for receiving said scrambled audio signals for removing the scrambling single side band signal component therefrom to recover said original audio information signals, said recovered audio information signals having a maximum frequency greater than the frequency of said carrier signal.

19. The system of claim **18** wherein the scrambled audio signals have a variable frequency component contributed by the scrambling modulation carrier signal, and wherein said generating means includes means for varying the frequency of the descrambling modulation carrier signal in a substantially identical manner to the variations in the scrambled audio signals.

20. The system of claim **19** wherein said variable frequency component of said scrambled audio signals comprises a swept frequency, and wherein said varying means includes means for continuously sweeping the frequency of said descrambling modulation carrier signal in substantially the same manner.

21. The system of claim **19** wherein said scrambled audio signals include associated first control signals specifying the start of frequency varying operations and second associated control signals specifying the frequency varying rate; and wherein said generating means includes means responsive to said first control signals for initiating said varying means and means responsive to said second control signals for establishing the varying rate.

22. The system of claim **18** wherein said processing means includes first phase shifting means for phase shifting the scrambled audio signals by 90°, second phase shifting means for phase shifting the descrambling modulation carrier signal by 90°, first double side band mixing means for mixing the scrambled audio signals with the descrambling modulation carrier signal, second double side band mixing means coupled to said first and second phase shifting means for mixing the 90° phase shifted version of the scrambled audio signals with the 90° phase shifted version of the descrambling modulation carrier signal, and means coupled to said first and second double side band mixing means for summing the output signals therefrom to remove the scrambling single side band signal component.

23. A method of scrambling audio information signals having frequency components lying within an original frequency spectral range, said method comprising the steps of:

(a) applying frequency pre-emphasis to the audio information signals;

(b) generating a modulation carrier signal at a frequency less than the maximum of the audio information signals; and

(c) signal side band modulating the audio information signals with the modulation carrier signal from step (b) to translate the frequency of said audio information signals in a given direction, without any filtering to remove the suppressed side band.

24. A system for scrambling audio information signals having frequency components lying within an original frequency spectral range, said system comprising:

means for generating a modulation carrier signal at a frequency less than the maximum of the audio information signals; and

a single side band processor having only a single mixing stage and having a first input coupled to said generating means and a second input for receiving said audio information signals for producing scrambled audio signals resulting from the single side band mixing of said modulation carrier signal and said audio information signals, without any filter for removing the suppressed side band.

25. A method of scrambling audio information signals having frequency components lying within an original frequency spectral range of about 50 Hz to about 15 kHz, said method comprising the steps of:

(a) generating a modulation carrier signal at a frequency lying within the original frequency spectral range, and

(b) single band modulating the original audio information signals with the modulation carrier signal from step (a) to translate the frequency of said original audio information signals in a given direction,

wherein said step (a) of generating includes the step of varying the frequency of the modulation carrier signal, and

wherein said step of varying includes the steps of initiating a frequency varying operation in response to a first control signal at a rate determined by a second control signal.

26. A method of scrambling audio information signals having frequency components lying within an original frequency spectral range of about 50 Hz to about 15 kHz, said method comprising the steps of:

(a) generating a modulation carrier signal at a frequency lying within the original frequency spectral range, and

(b) single side band modulating the original audio information signals with the modulation carrier signal from step (a) to translate the frequency of said original audio information signals in a given direction;

wherein said step (b) of single side band modulating includes the steps of phase shifting the original audio information signals by 90°, phase shifting the modulation carrier signal by 90° phase shifted version of the modulation carrier signal, double side band mixing the 90° phase shifted version of the original audio information signals with the modulation carrier signal, and summing the signals resulting from the double side band mixing steps to produce the desired scrambled audio signals.

27. A method of scrambling audio information signals previously scrambled by generating a scrambling modulation carrier signal at a frequency lying within the frequency spectral range of original audio information signals of about 50 Hz to about 15 kHz and single side band modulating the original audio information signals with the modulating carrier signal to produce scrambled audio signals containing a frequency translated version of the original audio information signals, said descrambling method comprising the steps of:

(a) generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal; and

(b) single side band modulating the scrambled audio signals with the descrambling modulation carrier signal to remove the scrambling single side band signal component and recover the original audio information signals;

wherein the scrambled audio signals have a variable frequency component contributed by the scrambling modulation carrier signal, and wherein said step (a) of generating includes the step of varying the frequency of the descrambling modulation carrier signal in a substantially identical manner as the variation in the scrambled audio signals; and

wherein said scrambled audio signals include associated first control signals specifying the start of a frequency varying operation and second associated control signals specifying the frequency varying rate; and wherein said step of varying includes the steps of initiating a frequency varying operation in response to said first control signals at a rate determined by said second control signals.

28. A method of scrambling audio information signals previously scrambled by generating a scrambling modulation carrier signal at a frequency lying within the frequency spectral range of original audio information signals of about 50 Hz to about 15 kHz and single side band modulating the original audio information signals with the modulating carrier signal to produce scrambled audio signals containing a frequency translated version of the original audio information signals, said descrambling method comprising the steps of:

(a) generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal; and

(b) single side band modulating the scrambled audio signals with the descrambling modulation carrier signal to remove the scrambling side band signal component and recover the original audio information signals; and

wherein said step (b) of single side band modulating includes the steps of phase shifting the scrambled audio signals by 90°, phase shifting the descrambling modulation carrier signal by 90°, double side band mixing the scrambled audio signals with the descrambling modulation carrier signal, double side band mixing the 90° phase shifted version of the descrambling modulation carrier signal, and summing the signals resulting from the double side band mixing steps to remove the scrambling single side band signal component.

29. A system for scrambling audio information signals having frequency components lying within an original frequency spectral range of about 50 Hz to abut 15 kHz, said system comprising:

means for generating a modulation carrier signal at a frequency lying within the original frequency spectral range; and

single side band processing means having a first input coupled to said generating means and a second input for receiving said scrambled audio information signals for producing scrambled audio signals resulting from the single side band mixing of said modulation carrier signal and said audio information signals;

wherein said generating means includes means for varying the frequency of said modulation carrier signal, and

wherein said generating means includes means responsive to a first control signal for initiating said varying means and means responsive to a second control signal for establishing the varying rate.

30. A system for scrambling audio information signals having frequency components lying within an original frequency spectral range of about 50 Hz to about 15 kHz, said system comprising:

means for generating a modulation carrier signal at a frequency lying within the original frequency spectral range; and

single side band processing means having a first input coupled to said generating means and a second input for receiving said audio information signals for producing scrambled audio signals resulting from the single side band mixing of said modulation carrier signal and said audio information signals; and

wherein said processing means includes first phase shifting means for phase shifting said modulation carrier signal by 90°, second phase shifting means for phase shifting said audio information signals by 90°, first double side band mixing means coupled to said first phase shifting means for mixing said audio information signals and the 90° phase shifted version of the modulation carrier signal, second double side band mixing means coupled to said second phase shifting means for mixing the 90° phase shifted version of the audio information signals with the modulation carrier signal, and means coupled to said first and second double side band mixing means for summing the output signals therefrom the provide the desired scrambled audio signals.

31. A system for descrambling audio information signals previously scrambled by generating a scrambling modulation carrier signal at a frequency lying within the frequency spectral range of original audio information signals of about 50 Hz to about 15 kHz and single side band modulating the original audio information signals with the modulation carrier signal to produce scrambled audio signals containing a frequency translated version of the original audio information signals, said system comprising:

means for generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal; and

single side band processing means having a first input coupled to said generating means and a second input for receiving said scrambled audio signals for removing the scrambling single side band signal component therefrom to recover said original audio information signals;

wherein the scrambled audio signals have a variable frequency component contributed by the scrambling modulation carrier signal, and wherein said generating means includes means for varying the frequency of the descrambling modulation carrier signal in a substantially identical manner to the variations in the scrambled audio signals; and

wherein said scrambled audio signals include associated first control signals specifying the start of frequency varying operations and second associated control signals specifying the frequency varying rate, and wherein said generating means includes means responsive to said first control signals for initiating said varying means and means responsive to said second control signals for establishing the varying rate.

32. A system for descrambling audio information signals previously scrambled by generating a scrambling modulation carrier signal at a frequency lying within the frequency spectral range of original audio information signals of about 50 Hz to about 15 kHz and single side band modulating the original audio information signals with the modulation carrier signal to produce scrambled audio signals containing a frequency translated version of the original audio information signals, said system comprising:

means for generating a descrambling modulation carrier signal having substantially the same frequency as the scrambling modulation carrier signal; and

single side band processing means having a first input coupled to said generating means and a second input for receiving said scrambled audio signals for removing the scrambling single side band signal component therefrom to recover said original audio information signals; and

wherein said processing means includes first phase shifting means for phase shifting the scrambled audio signals by 90°, first double side band mixing means for mixing the scrambled audio signals with the descrambling modulation carrier signal, second double side band mixing means coupled to said first and second phase shifting means for mixing the 90° phase shifted version of the descrambling modulation carrier signal, and means coupled to said first and second double side band mixing means for summing the output signals therefrom to remove the scrambling single side band signal component.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : **5,159,631**
DATED : **October 27, 1992**
INVENTOR(S) : **Ronald Quan and Ali R. Hakimi**

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 1, line 64, delete "]" second occurrence.

Col. 7, line 42, delete "∂" and insert --[--.

Col. 8, line 34, delete "Variation" and insert --variation--.

Col. 13, lines 21 and 22, Claim 5, delete "(A0, A1)".

Col. 14, lines 5, 6 and 7, Claim 11, delete "(A0, A1)".

Col. 14, lines 48 and 49, Claim 16, delete "(A0, A1)".

Col. 15, line 66, Claim 23, delete "signal" and insert --single--.

Signed and Sealed this

Sixteenth Day of November, 1993

Attest:

BRUCE LEHMAN

Attesting Officer *Commissioner of Patents and Trademarks*